

[0016] FIGS. 3-7 are shown to scale, though other relative dimensions may be used.

DETAILED DESCRIPTION

[0017] The following description relates to systems and methods for an all-wheel drive system of a hybrid electric vehicle. A hybrid electric vehicle, such as the hybrid electric vehicle shown by FIGS. 1-2, includes a front-wheel drive system and a rear-wheel drive system. The rear-wheel drive system includes an internal combustion engine mounted along a longitudinal axis of the vehicle and positioned at a front end of the vehicle. The engine is configured to supply torque to rear wheels of the vehicle via a drive shaft. The front-wheel drive system includes a first electric motor directly coupled to a first side of the engine and a second electric motor directly coupled to a second side of the engine, as shown by FIG. 3. Each electric motor may be a pancake motor including a cylindrical section, with a diameter of the cylindrical section being less than a length of the cylindrical section, as shown by FIG. 4. The length of the cylindrical section is positioned parallel to a mounting axis of each electric motor, and the mounting axis of each electric motor is positioned perpendicular to the longitudinal axis of the vehicle, as shown by FIG. 7. Each electric motor includes a reduction gearbox coupled to a different front wheel axle of the vehicle, with the first electric motor driving a first front wheel axle via a first reduction gearbox, and with the second electric motor driving a second front wheel axle via a second reduction gearbox. A housing of each electric motor may be coupled to an oil pan of the engine by a plurality of arms, with each arm extending from the cylindrical section, as shown by FIG. 6. The first electric motor may be additionally coupled to a first engine mount at the first side of the engine (as shown by FIG. 5), and the second electric motor may be additionally coupled to a second engine mount at the second side of the engine. By coupling the first electric motor directly to the first side of the engine and the second electric motor directly to the second side of the engine, an amount of space occupied by the front-wheel drive system may be decreased, and the electric motors may be driven independently in order to rotate the front wheels of the vehicle independently relative to the rear wheels (and to each other).

[0018] FIG. 1 and FIG. 2 each schematically show various components included by a hybrid electric vehicle 5. For example, FIG. 1 depicts an example of a cylinder 14 (which may be referred to herein as a combustion chamber) of internal combustion engine 10 included within vehicle 5, and FIG. 2 schematically depicts the vehicle 5 from a top view in order to further illustrate components of the vehicle 5 (e.g., components of a front-wheel drive system 183 and a rear-wheel drive system 185 described below with reference to FIG. 1). Some components shown by FIG. 1 may not be shown by FIG. 2 (or vice versa) for illustrative purposes.

[0019] Turning firstly to FIG. 1, cylinder 14 of engine 10 is shown to include cylinder walls 136 capped by cylinder head 159. The cylinder 14 includes a piston 138 positioned therein. Piston 138 is coupled to crankshaft 140 so that reciprocating motion of the piston is translated into rotational motion of the crankshaft. Engine 10 may be controlled at least partially by a control system including controller 12 and by input from a vehicle operator 130 via an input device 132. In this example, input device 132 includes an accel-

erator pedal and a pedal position sensor 134 for generating a proportional pedal position signal PP.

[0020] Engine 10 is configured to provide torque to the rear-wheel drive system 185 of the vehicle 5 via crankshaft 140. Specifically, crankshaft 140 is coupled to transmission 54 and provides input torque to transmission 54, with the transmission 54 being a gearbox, a planetary gear system, or another type of transmission. The transmission 54 converts the input torque into an output torque via a plurality of gears internal to the transmission 54, and the output torque is provided to the rear wheels of the vehicle by the transmission 54 in order to drive the rear wheels.

[0021] In some examples, the rear-wheel drive system 185 of the vehicle 5 may additionally include electric machine 52 configured to provide torque to first rear wheel 163 and second rear wheel 161 via transmission 54. For example, electric machine 52 may be connected (e.g., coupled) to transmission 54 in order to drive transmission 54 and provide torque to first rear wheel 163 and second rear wheel 161 during conditions in which one or more clutches are engaged. In the depicted example, a first clutch 56 is provided between crankshaft 140 and electric machine 52, and a second clutch 57 is provided between electric machine 52 and transmission 54. Controller 12 may send a signal to an actuator of each clutch (e.g., first clutch 56 and/or second clutch 57) to engage or disengage the clutches, so as to connect or disconnect crankshaft 140 from electric machine 52 and the components connected thereto, and/or connect or disconnect electric machine 52 from transmission 54 and the components connected thereto. Electric machine 52 receives electrical power from a traction battery 58 to provide torque to first rear wheel 163 and the second rear wheel 161. Electric machine 52 may also be operated as a generator to provide electrical power to charge battery 58, for example during a braking operation.

[0022] The rear-wheel drive system 185 may be configured to operate in various manners including a parallel configuration (e.g., with torque provided to the rear wheels by both engine 10 and electric machine 52), a series configuration (e.g., with torque provided to the rear wheels by one of the engine 10 or the electric machine 52, and with the other of engine 10 or electric machine 52 providing electrical energy to the vehicle 5), or a series-parallel configuration. In other examples, the vehicle 5 may not include the electric machine 52, with the rear wheels being driven by the crankshaft 140 of engine 10 as described above.

[0023] The front wheels of the vehicle 5 (e.g., first front wheel 167 and second front wheel 165) are not driven by engine 10. Instead, each front wheel is driven by a respective electric motor, with the driving of the front wheels being independent relative to the driving of the rear wheels (e.g., by rear-wheel drive system 185 as described above). Specifically, the front-wheel drive system 183 includes a first electric motor 175 coupled to the first front wheel 167 via a first reduction gearbox 179, and the front-wheel drive system 183 additionally includes a second electric motor 173 coupled to the second front wheel 165 via a second reduction gearbox 177. By driving the front wheels independently relative to the rear wheels, a traction of the front wheels (e.g., a frictional force between front wheels of the vehicle 5 and a ground surface on which the vehicle 5 sits) may be increased in order to more easily drive the vehicle 5. For example, during conditions in which the rear wheels are unable to provide sufficient traction to drive the vehicle 5